A lifestyle-based scenario for U.S. buildings: Implications for energy use

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Abstract

Can lifestyle-based scenarios provide insight into the nature of energy use in our future buildings? Participants in a design charrette brainstormed ideas about the future of US homes and workplaces. The teams started from several descriptions of daily lifestyles, and developed specific building characteristics as the place settings for these narratives. In addition to characterizing the physical environment, the teams also identified the forces that would be influential in making these changes. Further reflection was made on the possible unintended consequences of these changes. The energy implications of these changes were characterized with respect to magnitude and direction. While acknowledging the speculative nature of the

exercise, the rationale was to broaden the discussion on future energy use by looking at future scenarios in the context of everyday life.

Keywords: lifestyle, energy, buildings

1. Lifestyle-based energy forecasting

Forecasts of energy use make assumptions about the way we live and work and how this will change over time. As an exercise we asked the question: What might our homes and workplaces be like in the year 2020 and what forces will bring about these changes? The effort was not to set a utopian vision for our future buildings, but to look at what might be reasonable changes to expect for our homes and workplaces in the near future.

Several authors in the past 20 years have looked at lifestyle-based energy scenario forecasting. Paul Hawken and his colleagues in the early 1980s looked at how access to energy and resources led to different lifestyle scenarios (Hawken, Ogilvy, & Schwartz, 1982). Lee Schipper and colleagues reviewed demographic trends and other lifestyle factors in developing different energy scenarios for the US and elsewhere (Schipper & Meyers, 1993). More recently, the Intergovernmental Panel on Climate Change has identified four scenarios based on different economic and population growth worldwide to look at energy consumption and greenhouse gas emissions (Carter et al., 2000).

By developing lifestyle-based scenarios, we could then ask questions about the energy implications of these changes, and how might we create energy policies to

take these changes into account. The assumption here is that energy is an integral factor of how we live, work and play, and to understand future changes in energy demand we need to understand the dynamic nature of how our changing lifestyles interact with the built environment.

2. Methodology

Forecasts for energy use in buildings take a variety of forms. One approach is to take inputs such as future housing starts, appliance saturations, predicted energy costs, demographics, etc., and construct regional or national models to forecast energy use trends.

The approach taken here was based on hypothetical lifestyle analyses, and asked the question, what might our future lifestyles be like, and how would our homes and workplaces reflect these activities? The assumption here is that if we understand lifestyle choices we would have a better insight into the environmental settings that will be needed to meet these lifestyles.

The method to generate these scenarios was that of a design "charrette". A charrette is an intense design exercise that has small teams of people working on a clearly defined objective under considerable time pressure. The intent is to generate imaginative and compelling ideas that can later be tested for practicality or other rational checks.

The charrette was conducted in February 1997 by staff of the Environmental Energy Technologies Division of Lawrence Berkeley National Laboratory. The thirty participants in the charrette were randomly assigned to teams. Each team was given a narrative of a family that represented a specific demographic characteristic. Families differed by size, age, region, education, and income. Each team was to envision a day in the life of their family, at home and at work. Based on these narratives, the teams would then develop the built infrastructure to support these narratives. As an example, one team followed the activities of the Sherman family, as they got up, prepared breakfast, bathed and set out for school and work. Following their work at an assembly plant and local school, the family came together for dinner and evening activities at home. By linking technologies to specific lifestyle activities, we hoped to avoid the trap of simply brainstorming new technologies for the sake of new technology.

3 Results

There was general consensus that the buildings of the year 2020 would be different from the buildings of today. These changes reflect the desires of building owners, the evolving needs of employers and households and the variety of factors that shape the building industry.

We identify two primary areas of change for the buildings in 2020. The first area speculates on the *technological* changes that will influence our homes and

workplaces. The second area looks at changes in the *process* by which buildings are designed, constructed and operated.

If we were to identify one single area where we see the greatest potential for change, it would be in the growth of information technologies. Changes in how we produce, transmit, collect, interpret and store information will continue to have a major impact on our buildings.

3.1 At Home in the Year 2020

In the year 2020, American families will spend more time in the home, both for work and for recreation. The workweek will be shorter and the three-day weekend the norm. Time is the most important commodity, so timesaving features are valued. There will be an increase in still more electronic equipment in the home, e.g., wall-sized screens for watching home movies as part of home entertainment. Cooking at home is increasingly popular, with more sophisticated convective and microwave ovens the norm. Other options for food preparation include having groceries and pre-cooked meals ordered electronically on the internet and delivered to the home. Also, more food will be grown locally, and farmers' markets will be increasingly popular.

The interest in personal physical fitness will continue, leading to the development of more communal exercise facilities and pools, especially in apartment complexes. After years of decreasing household size, households will increase to accommodate extended family members living together. One result will be the presence of someone at home most of the time. Full in-law apartments, with, bath, bed, living, workspace will be retrofit on existing

homes and featured in new housing. With the continuing deterioration of the physical condition of schools, many kids will stay home during the day and telecommute to their classes.

In a reversal of the flight to the suburbs, due in part to increased traffic, many households will move back to the urban centers—seeking access to entertainment facilities, closer neighborhood communities, and economic opportunity.

The design of new houses

New houses are all super-insulated and weather-tight, (air changes due to infiltration below 0.3 ACH), with mechanical ventilation including filtration systems to remove particles such as pollen (to reduce allergies). An additional benefit of the filtration system is the reduction of dust and less need for dusting and cleaning.

The houses will have minimal thermal mass in the structure to provide optimal dynamic space conditioning except in cases where the thermal mass is an integral part of a passive solar strategy. New window technologies will include automatic shutters for storm protection, smart windows for privacy, and higher thermal performance for both energy savings and comfort.

Historical renovation will become increasingly important as people restore older houses, making improvements in energy efficiency and comfort while respecting the historical value of their dwellings.

Heating, Cooling & Ventilation

Comfort and control will be the driving factors for residential mechanical equipment and appliances. The equipment in housing will continue to have increased building automation, with remote control for heating, cooling and lighting for individual areas. Individual control will improve zoned and whole-house heating, cooling and ventilation with heat recovery and good filtration. Certain regions of the country will see increased use of radiant heating and cooling systems in walls and floors, with air movement provided only for ventilation.

Increased concern for providing a healthy home will lead to the development of pollutant detectors controlling ventilation as part of a "smart" ventilation system. Residential air conditioning is ubiquitous—with quiet fans—but demand for cooling will be lower due to better building design, roof coatings and shading.

Baseload space conditioning (heating and cooling) will be met with ground-coupled hydronic loops, with heat pumps where necessary. Dehumidification of outdoor air will be provided by desiccant systems operated by waste heat rejected from other appliances.

Household Appliances

Household appliances will continue to improve in energy efficiency and will be smaller and quieter. Advanced appliances include small portable microwave washers and dryers.

Bath & Laundry

Bathrooms will have water-efficient appliances and other features such as self-cleaning shower stalls. High-tech, energy-efficient laundry system will sort dirty clothes into separate bins and operate the washer and drier when full.

Lighting

Residential lighting will use solid-state devices and be fully dimmable. Advanced lighting will be integrated with the walls and ceilings. Light-tubes will bring daylight to interior and basement areas.

Home Automation: Sensors & Controls

A new network of sensors and controls will integrate all the building services. Home security systems will be integrated with exterior lighting. Sensors will control the heating and cooling of only occupied spaces. Air quality and humidity sensors will assess the need for ventilation.

Home entertainment systems will become increasingly sophisticated. No more video-display television and computers—all televisions and monitors will be flat screen.

Landscape & Community

Residences will develop more contact with outdoor spaces, both through gardens and patios for single-family and rowhouses and with balconies and roof gardens for apartment buildings. Green streets will flourish. Millions of new trees will be planted and maintained in downtown areas. Suburban areas will develop nearby community centers with office space, childcare and recreational facilities.

Energy Supply

Solar energy will be more widespread for residential use. Integrated photovoltaic (PV) panels will be increasingly common on roofs. The PV units will have battery storage as well as be connected to the grid. Neighborhood solar generation facilities will produce up to 10% of the residential energy needs.

Decentralized power—fuel cells—will be owned and operated by a power service company. Fuel cells in residences will provide full electricity and partial space heating and water heating from natural gas. Reliability of home energy supply becomes essential because of all the home management systems, which may require two sources of electricity supply to handle this.

3.2 How we Work in the Year 2020

Compared to the general agreement among the teams about the future of our housing, there was little consensus among the charrette participants about the nature of how we will work in the Year 2020. Some argued that we would work less than

40 hours per week and have more hours to pursue leisure activity. Others argued that economic pressures would continue to drive more people to work additional hours and jobs.

Similarly, there were different views on the importance of home-based work. Some people felt we would see continued development of the home-based office, with greater amounts of office equipment in the home. Others expect to see less home-based work, as people re-discover the value of human interaction. The need for human interaction would lead to more cafes and informal settings in the work environment—you go to the office cafe to have meetings and interact with people at work. And for those who can't leave their work behind, there would be more work environments in cafés—already tables have terminals and Internet connections for laptops in bars and airport restaurants.

Workplaces will operate 24-hours a day due to multinational business hours crossing all time zones. Individuals will not be assigned to individual office space, but will select what space they need from a variety of options. Voice or fingerprint recognition will provide access to personal files from any workstation. We will have more electronic equipment at work and in our vehicles for transit to and from work.

Transportation options include small personal vehicles for urban transit, and there will be increased reliance on shuttles and public transit. Electric light-rail stops two-blocks from every doorstep. A state-of-the-art hydrogen fuelcell powers the weekend automobile.

Workplace Design

The nature of the workplace is expected to change, with more mixing of business and retail settings—full banking services will be provided in fast-food restaurants, supermarkets and elsewhere.

Workplaces will reflect worker preference for private offices, not corporate preferences for open-plan designs. Workers will demand more comfort and control over environmental conditions. Management will be more responsive to the costs associated with worker productivity and health.

HVAC & Equipment

Commercial buildings will have more local control of heating, lighting, cooling and ventilation. Work environments will separate ventilation from thermal conditioning—no recirculation of indoor air. Ventilation will be 100% filtered and conditioned outside air, and where appropriate, conditioned by desiccants with waste heat generation. The trend will be for better ventilation in the workplace, improved equipment maintenance and selection of low-polluting materials, all of which will lead to reduced incidences of building-related illness.

Thermal conditioning (heating and cooling) strategies will include radiant systems, ventilative cooling where diurnal swing is sufficient, ground-source heat pumps for thermal conditioning and pre-conditioning of outdoor air by ground coupling and heat recovery. Integrative design will allow for exhaust of convective heat from

equipment and lights, with heat recovery where needed. Electrical circuits will be separated for different voltages to reduce the need for transformers in the conditioned space.

We will continue to see greater concentrations of electronic equipment in all work environments. Smart equipment and appliances will routinely power down when not in use.

Sensors & Controls

More wireless equipment will be commonplace. Personal electronic greeters will recognize your voice or handprint and automatically adjust the temperature and light in the workspace to the preference of the individual.

Energy Supply

Commercial buildings will make expanded use of renewable energy sources (wind, solar) where appropriate. Photovoltaics will be integrated into building walls and roofs. Decentralized co-generation units will use waste heat integration to increase fuel efficiency.

4. The Construction and Operation of Buildings in the Year 2020

We will see more performance-based fees for designers and builders for the construction and rehab of commercial buildings. Instead of compensation based only

on project cost and size, payment will include a provision for compensation (or penalty) based on actual building performance.

Companies will offer performance-based contracts for building services, e.g., \$0.50/ft^2 (5 Euro/m^2) for heating, cooling and lighting, with maintenance included, for both apartment complexes and workplaces.

Construction practices will feature modular systems, for both HVAC components and construction materials. We expect to see more durable building materials with less outgassing from construction materials of all kinds.

Construction financing will be available from the federal government under a new program, which will offer low-cost loans for energy-efficient mortgages. Other financing strategies will include self-financing by co-ops and corporate foundations. Insurance companies will offer discounts on insurance premiums due to increased security (energy-efficienct, non-flammable materials) and more buildings will be owned by insurance companies.

Changes will continue to be driven by codes and industry-driven labeling for construction materials and buildings. Historical renovation and conflicts with building codes will continue.

There will be increased demand for high quality housing, with a rediscovery of knowledge and skill in the building trades.

Residential construction will become increasingly consolidated by a few large corporate builders, following the Swedish model. Pre-fab construction components will be brought to site for assembly, using local labor from economically depressed neighborhoods.

5. What are the driving forces that will bring about these changes?

Changes in the building sector are inevitable. The variety of competing demands and interests by the various key players and institutions will ensure that buildings in the year 2020 will be different from the buildings of today.

In the previous section we speculated on the changes that we expect to see in our homes and workplaces. In the next section we look at what are some of the forces in society that will bring about these changes.

5.1 Key Players & Roles

The group identified several individuals and institutions that would play a role in shaping our future built environments. These ranged from the predictable to the often light and humorous:

Energy Service Companies (ESCOs). These were seen as new providers of guaranteed lighting, heating, cooling services. Instead of utilities providing energy, ESCOs would provide energy services directly to customers.

Financial community. Bankers and lenders would develop innovative financing for performance contracting and other strategies for energy services.

Developers & Builders. The construction industry would be increasingly streamlined, with more fast-tracking to reduce the costs of construction related to the length of the process. Builders would routinely guarantee residential energy bills.

Prominent individuals. "We'll do whatever [Microsoft CEO] Bill Gates wants." "If [popular American style guru] Martha Stewart shows how energy conservation is compatible with style, we'll follow".

Community/Government. The importance of local codes and standards will continue to shape the energy intensity of new construction. Urban renewal plans, middle-income housing subsidies and investments in eco-friendly technologies will be commonplace in some communities. Community planners will develop land-use design strategies that are resource efficient.

Federal government. The federal government will establish loan programs for energy-efficient mortgages, as well as an increased funding for R&D on energy efficiency and renewables.

Education. Schools and universities will have degree programs to educate future architects in energy efficiency as well as general courses on the impacts of non-efficient consumption and development on the environment.

Insurance industry. The insurance industry, recognizing the global costs of climate change will offer financing (profit driven) for energy-efficient contruction and retrofit.

5.2 Key Drivers for changes in the 2020 Buildings

Buildings in the past 25 years have responded due to changes and perceptions of change in several areas of society. Energy shortages, perceived and real, environmental costs, political leadership (and its lack) have all influenced how buildings have been designed and operated.

In the coming decades we expect to see the following issues as potential drivers for changes in the energy use in buildings.

1. Increased competition among utility service providers leading to new services and products.
2. Economic incentives—profitability based on building performance.
3. More partnering between players in the building sector. Because of more specialization, organizations are going to have to communicate, negotiate and work together more.

4. Prolonged heat waves or other increased natural disasters as clear sign of global warming stimulating the insurance industry and others to pursue energy conservation strategies.

5. Fossil-fuel prices have an additional 50% carbon tax added for environmental externalities.
6. Greater awareness of indoor air quality problems by the public and the legal profession.
7. Developments of new technologies, e.g., LED and fuel cell technology, electrochromic windows, flat panel displays, and integrated communication and controls.
8. Consumer education to value energy efficiency and the indoor environment.
9. Service-based rather than resource-based billing—all costs combined in one bill.
10. Increased demand for energy efficiency in the military and public housing due to downsizing and privatization.
11. Need for Federal government to impartially evaluate the natural, political and market forces—who gains, who loses?
12. Need for Federal government to accelerate or shift the market towards these goals through RD&D.

6. What are possible unintended consequences of these changes?

Several of these drivers could improve the energy efficiency of buildings, but have unintended consequences in other societal areas. We feel it is important to try to identify the unintentional consequences of these activities in order to prevent or reduce their impact. For this reason we included in the list above the Federal role to evaluate these drivers and to determine the benefits and losses.

As examples of unintended consequences we give the following examples:

- The integration electronically of communications, business, entertainment, etc., could lead to catastrophic failure.
- Greater electronic integration could lead to loss of privacy—more calls from telemarketers at dinnertime.
- Streamlining the construction process could lead to losses in quality of buildings and to greater destruction of the environment.
- Increased reliance on the electronic communications can raise issues of social equity for those without or with limited access.
- More automation could lead to sedentary lifestyles and increases in health problems.
- Greater investment in middle-income housing could lead to less public support for low-income housing.
- Increased immigration as US standard of living increases.
- Community-based planning can exclude people and restrict individual freedom of choice.
- It is difficult both to optimize energy strategies and to be flexible with respect to maintaining several options.

A major reservation of this "charrette" approach was that the future lifestyles were envisioned by a group of people not representative of the full range of lifestyles that they were to describe. Would a different group of people have arrived at a different vision? While this is certainly open to testing, the idea here was to see whether such

an approach would give new insight to the way that we currently forecast energy use.

7. Implications for future energy use

As stated in the introduction, one of the goals for the exercise was to develop lifestyle-based scenarios for looking at how energy use might change in the year 2020. Several factors were identified, but there was no specific analysis on how they would impact energy use. Table 1 summarizes how these factors might influence energy consumption in future residences.

The factors that may have the largest impact on future energy use in residences are the number of people at home and the number of hours that the home is occupied. Since people are the primary users of energy, it is not surprising that number and hours of use will dominate. As the notes indicate, many of these trends in the residential sector could have changes in energy use that have offsets in other sectors. As an example, if people are home more of the time, then they may use less energy in the workplace (if workplaces have the flexibility to reduce energy use during periods of lower occupancy). People working at home may also make more local trips with their cars, because of fewer constraints to travel in peak times, which would lead to increasing energy use in the transportation sector.

Table 2 shows the impact of changes in future building design and use on the energy consumption in workplaces. The factors with the largest potential for increasing or decreasing energy use in the workplace are the number of hours people are working.

But the decrease in energy use would only be realized if buildings were sensitive to the demands for services. If a building is operated 24 hours a day, independent of usage patterns, reducing occupancy will only show minimum reductions in energy use, primarily from reduced equipment usage. Changes in the building and equipment are probably less significant than the demand for building services.

8. Conclusions

The changes in energy use in buildings identified by the charrette participants were based on multiple lifestyle scenarios. Because of the large overlap among the individual scenarios, they were then combined into one general scenario. What was lost was some of the specificity for certain populations, e.g., low-income, elderly, unemployed, very-high income, etc., as well as regional variations. Nevertheless, the general findings were remarkably consistent across the different teams. One reason for the consistency was that the participants themselves, while asked to identify with families representing different lifestyles, may have overly relied on their own experience.

The key strength to the "charrette-style" scenario development is that, unlike most forecasting exercises, which use a limited data set and parameters for computer-based projections, people can integrate a vast quantity of interrelated materials in a very short period of time. This ability is especially relevant when we are looking at lifestyle choices related to how we live and work in buildings.

The use of such an exercise is to identify *possible* scenarios, which can then be studied in more detail. If such topics as home-based offices, distance learning, personal HVAC controls, and home-delivered meals are viewed as likely developments, then these can be investigated in more detail to understand the links between the services provided and the energy use consumed. A further benefit from the exercise was in identifying the possible unintended consequences of these changes. If we focus only on the energy implications of new technologies, we may miss how these new developments in our homes and workplaces affect other aspects of how we live and work.

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Table 1. Impact of Changes on Future Residential Energy Consumption

Nature of change	Direction of change [up, down, same]	Magnitude of change [small, medium, large]	Notes
Greater household size w/ extended families	↑	large	
More time at home	↑	large	Possible decreased energy use elsewhere
More electronic equipment at home	↑	medium	
More efficient appliances	↓	medium	
Improved thermal envelopes and windows	↓	medium	
Reduced cooling needs	↓	medium	
Zoned HVAC control	↓	medium	
Increased cooking	↑	small	Possible decreased energy use elsewhere
Mechanical ventilation systems	↑	small	Greater outside air rates require more conditioning.
Reliability requirements	↑	small	
More delivered meals	↓	small	Possible increased energy use elsewhere
Integrated lighting	↓	small	
Renewable energy sources	↓	small	

Table 2. Impact of Changes on Future Workplace

Energy Consumption

Nature of change	Direction of change [up, down, same]	Magnitude of change [small, medium, large]	Notes
More time in the workplace	↑	large	
Less time in the workplace	↓	large	
More electronic equipment at work	↑	medium	
Mechanical ventilation systems	↑	medium	
Integrated lighting & daylighting	↓	medium	
Reduced cooling needs	↓	medium	
Improved thermal envelopes and windows	↓	medium	
More efficient appliances, with smart controls	↓	medium	
New workplace settings, e.g., airports, restaurants, cafés, etc.	↑	small	Possible decreased energy use elsewhere
Extended workplace hours	↑	small	
Reliability requirements	↑	small	
Zoned personal HVAC control	±	small	Unknown performance of new technologies
Separate electrical circuits	↓	small	
Renewable energy sources	↓	small	